Video Analysis

Real-World Explorations for Secondary Mathematics

By Joel A. Bryan

Subject: Graphing, functions, physics

Grades: 9–12 (Ages 14–18)

Technology: Digital video, video analysis software, spreadsheets

Standards: *NETS•S* 3 (http://www.iste.org/nets/). *NCTM* Grades 9–12 Algebra (http://standards.nctm.org/document/).

Secondary math students are often heard to ask these two timeless questions: "When are we ever going to use this?" and "Why do we need to know this?" We must be able to provide satisfactory answers to these questions, because students who fail to realize the relevance of content covered in class are often less successful than those who do see the immediate value of the knowledge.

Although many math instructors may struggle to find authentic examples of function and graphing applications that hold the interest of their students, physics instructors like me have long known of numerous applications encountered in studies of motion. Quantities relevant to motion studies include position, time, velocity, acceleration, force, momentum, impulse, and forms of energy. Descriptive quantities for objects moving with constant velocity are generally expressed by linear and/or constant relationships, while accelerating objects are generally described by both linear and quadratic functions. Objects undergoing periodic motion, such as objects rotating or moving in a circular path, yield trigonometric functions when position, velocity, and/or acceleration are plotted with time.

Barriers to Authentic Investigations

These real-world investigations rarely enter the math curriculum, due in part to teacher perceptions (whether real or imagined) of time constraints, cost and safety restraints, availability of materials, preparation for high-stakes testing, and a general lack of awareness of what could be done. Even while teaching algebra and discovering firsthand that my students grew more attentive when I used common physics examples to describe authentic reasons for learning about functions and graphing, I never had my students perform any authentic data collection experiments. Unlike many other math teachers, I knew what could be done and had access to all the necessary equipment, but like them, I also had perceptions that there was not enough time to stray from the required curriculum to do "experiments" in class, and that the hassles of setting up experiments was not worth the effort. Now, however, I see video analysis as a solution to all these barriers.

Currently Available Programs

A number of relatively inexpensive video analysis programs are currently available, including Measurement-in-Motion, VideoPoint, and Physics ToolKit (formerly known as World-in-Motion). Of these programs, VideoPoint has the most features and is perhaps the most versatile, although Physics ToolKit is the least expensive (currently $50 for a site license) and comes equipped with video clips that I consider to be more suitable for introductory physics studies.

Macintosh users may prefer Measurement-in-Motion, which was originally designed for exclusive use with Macintosh computers, although it has recently become available for use with Windows-based personal computers. Rising interest in this type of technology and the awareness of its potential for enhanc-

ing student learning has led makers of calculator-based software and probes, such as Vernier's LoggerPro, to incorporate similar video analysis capabilities into their existing programs. In addition to these and other currently available programs, similar programs are being developed for use with handheld computers, which should greatly increase the versatility of video analysis as an instructional tool. (***Editor's note:*** Find information about these and other resources on p. 24.)

With these programs, students can "mark" the position of an object in each frame of a video clip to obtain position information, then quickly and easily produce informative graphs of position, velocity, acceleration, force, momentum, and energy with just a click of the mouse button. Students may either analyze video clips that are supplied by these programs, import video clips from other sources, or produce their own video clips.

Two video analysis programs may be downloaded from the Web free of charge: Tracker and DataPoint. Tracker contains many of the same features contained in the previously described commercial programs. Students mark video frames, set the origin to the desired location, and calibrate the video for real-world measurement values. Tracker then calculates motion values, constructs graphs, and draws and manipulates force, velocity, and acceleration vectors. The Tracker Web page contains links to tutorials and several video clips ready for analysis. Tracker also has the capability of creating a line profile tool that measures the brightness of the image pixels it lies on to generate spectral line profiles and analyze diffraction and interference patterns, a feature not currently available with other video analysis programs.

Students using DataPoint mark video frames in a similar manner, but they must import the marked data into a spreadsheet for manipulation and graphing. To obtain more meaningful results, students using this program must convert their data sets, which contain *x* and *y* pixel positions of the location of the object with time, to appropriate position units using proportions and a known measurement standard placed in the video clip. Users may also need to make linear translation manipulations to move the origin to a desired location.

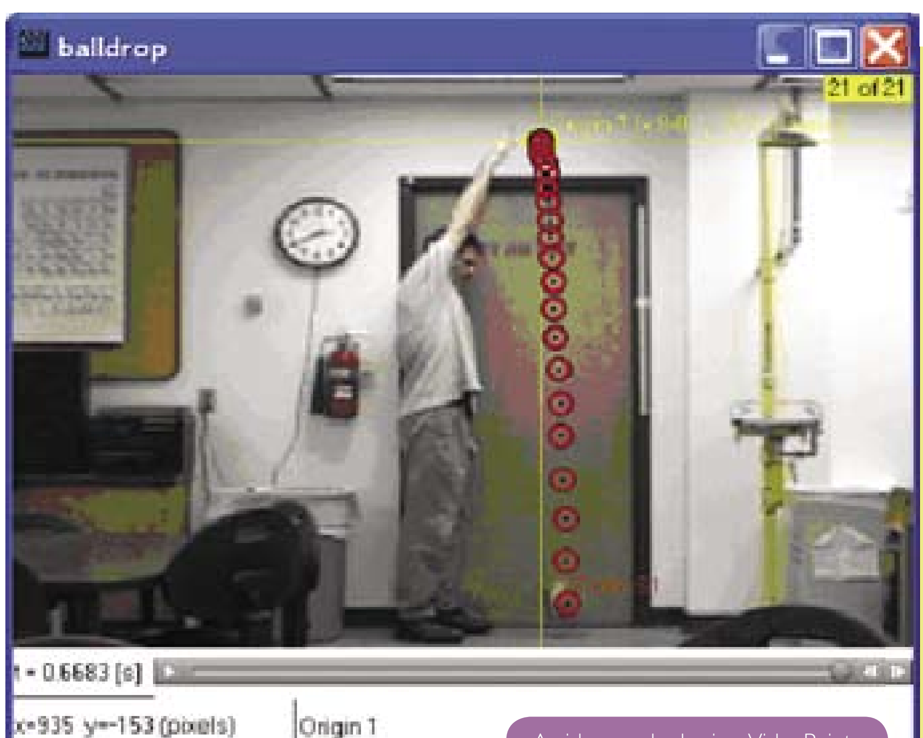
A video analysis page linked to the Texas A&M University Center for Mathematics and Science Education (CMSE) Web site contains 19 short video clips that may be downloaded and analyzed using any of these programs. Also linked to this Web site are instructional videos demonstrating the use of VideoPoint, DataPoint, and Excel for data analysis, along with suggestions for the use of each video clip.

An Example

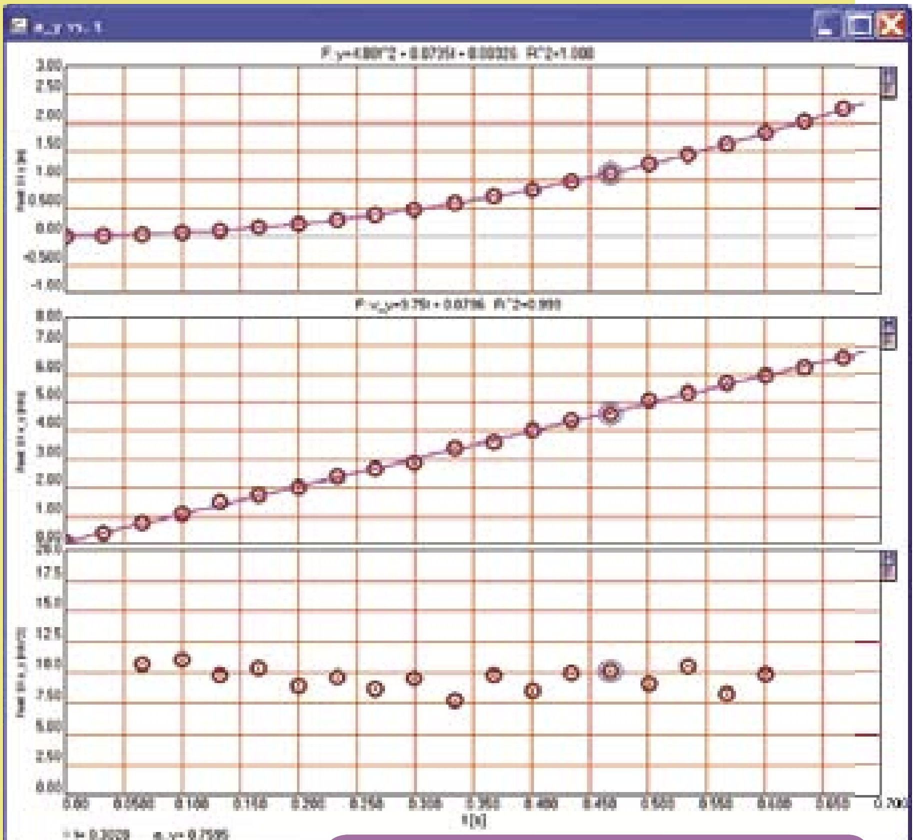
Preservice middle-grade math and science teachers at Texas A&M University use video analysis technology in my technology-rich conceptual physics course. The four video analysis lab investigations conducted by student pairs in this semester-long course include topics of constant and accelerated motion, objects falling with and without significant air resistance, the conservation of mechanical energy in a bouncing ball, and circular motion. Such studies result in motion data that are represented in whole or piece-wise by linear, quadratic, and sinusoidal functions. Most of these software programs will also make graphs of angular positions, velocities, and accelerations.

In addition to modeling these mathematical relationships, one benefit of video analysis technology is that students may view multiple representations (e.g., a pictorial view, tables of numbers, graphs, mathematical formulae, and verbal/written descriptions) of the same information.

In the marked video of a falling mini-basketball using the VideoPoint program, students see visual evidence (the increasing space between marks) that the object increased its speed as it fell.



A video marked using VideoPoint.



Falling ball: position, velocity, and acceleration graphs.

Because there are 30 frames per second in the digital video clip, students mark each frame by moving the cursor over the object in each frame and clicking to yield precise locations of the accelerating ball every 1/30 second. Students use the meter stick taped to the door frame for scaling purposes of converting pixel locations to meter locations. Students click to highlight the origin and drag it to the highest position marked. They then rotate the axes so that the positive vertical direction is downward. After students click on the conveniently placed toolbar graphing icon and select plots of position, velocity, and acceleration of the falling ball's *y*-coordinate with time, the software program generates graphs.

VideoPoint allows both automatic fitting of an equation, such as those shown on the three graphs, or student modeling through trial and error to determine the best-fit equation for each graph. In addition to discussing the equations of each graphical representation and the physics behind their interpretations (e.g., in the position-time graph, the coefficient of the t^2 term is one-half of the object's acceleration, the coefficient of the t term is the object's initial velocity, the slope of a velocity-time graph is the object's acceleration, etc.), instructors may use these three graphs to illustrate applications of the first and second derivatives of a quadratic equation. Students may also use VideoPoint to quickly and easily investigate instantaneous changes in the graphs when the origin is translated and/or rotated.

After analyzing the falling ball with insignificant air resistance, I then have my students investigate a balloon falling with significant air resistance. With this software, students determine the terminal velocity of the balloon and how far it fell before reaching terminal velocity and compare these outcomes and graphs with the previous experiment's results.

Summary

Although I no longer teach high school physics or math, I heartily recommend this sophisticated, yet inexpensive and simple to use, technology for use in not only physics and physical science courses but also in all levels of secondary math. Video analysis methodology eliminates the most common barriers to incorporating real-world investigations into math studies and economically facilitates authentic investigations and applications of graphical, mathematical, and numerical representations to real-world problems and data.

Resources

Bryan, J. (2004). Video analysis software and the investigation of the conservation of mechanical energy. *Contemporary Issues in Technology and Teacher Education* [Online serial], *4*(3). Available: http://www.citejournal.org/vol4/iss3/science/article1.cfm

DataPoint: http://www.stchas.edu/faculty/gcarlson/physics/datapoint.htm

Measurement in Motion: http://www.learninginmotion.com/products/measurement/

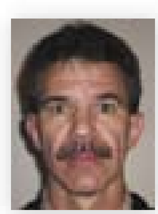
Physics ToolKit: http://members.aol.com/raacc/wim.html

Texas A&M Center for Mathematics and Science Education Video Analysis Web Page: http://www.science.tamu.edu/CMSE/videoanalysis/

Tracker: http://www.cabrillo.edu/~dbrown/tracker/

Vernier's LoggerPro 3: http://www.vernier.com/soft/lp.html

VideoPoint: http://www.lsw.com/videopoint/



After teaching high school physics and math for 13 years, science educator Joel A. Bryan currently teaches a Texas A&M University technology-rich conceptual physics course for preservice middle-grade math and science teachers and is active in professional development for science and math teachers.